Mesaverde Group

Gas from Mesaverde Group reservoirs is found in both structural and stratigraphic traps. Some reservoirs, like those in Natural Buttes Field, are part of larger, basin-centered gas traps where the gas collects downdip from more permeable water-filled reservoirs. Average depth to the top of productive reservoirs ranges from 1300 to >8500 feet.

The terminology of the Mesaverde Group is complex, due to facies changes that occurred as the Cretaceous Interior Sea transgressed and regressed along its western margin in the Piceance-Uinta Basin area. The Mesaverde consists of three dominant reservoir facies: lenticular, fluvial sandstones of the Williams Fork Formation, coals that occur in the basal portion of the Williams Fork Formation, and extensive shoreline-marine sandstones of the Iles Formation.

The fluvial sandstones of the Williams Fork Formation are approximately 4000 feet thick in the eastern part of the Piceance Basin, thinning to <2000 feet on the Douglas Creek Arch and 2200-2900 feet in Natural Buttes Field in the Uinta Basin. These sandstones are lithic arkoses and feldspathic arenites containing authigenic quartz and carbonate cement. They have low porosities, ranging from 7-12%, and low matrix permeabilities (<0.1 mD) due to the abundance of authigenic clays.

The shoreline-marine sandstones of the lower Mesaverde Iles Formation were deposited during transgressive and regressive cycles along northeast-southwest trending shorelines. These sandstones merge with fluvial facies to the northwest and the Mancos Shale to the southeast. The most productive members are the Cozzette, Corcoran, and Castlegate Sandstones.

The Castlegate Sandstone is a clean, fine-grained, subarkose to sublitharenite, with low porosity and permeability due to pore-filling authigenic clays. It was deposited along ancient shorelines or as offshore bars. In the southeastern part of the Uinta Basin, 50-70 feet thick Castlegate sandstones produce from structural traps at depths of 8000 feet. Permeabilities range from 0.5-0.9 mD. All fields that produce from the Castlegate involve some type of structural closure, and several close against faults. Production rates are enhanced by the associated tectonic fractures.

Source rocks for gas produced from the fluvial sandstones at Natural Buttes Field are coals and carbonaceous shales. The source for the shoreline-marine sandstones is probably the Mancos Shale. Porosities of the Mesaverde Group sandstones remain unusually stable over a large vitrinite reflectance interval (FIGURES UO-11 and UO-12), implying that sparsely explored deep central basins may hold some promise (Tremain, 1993).

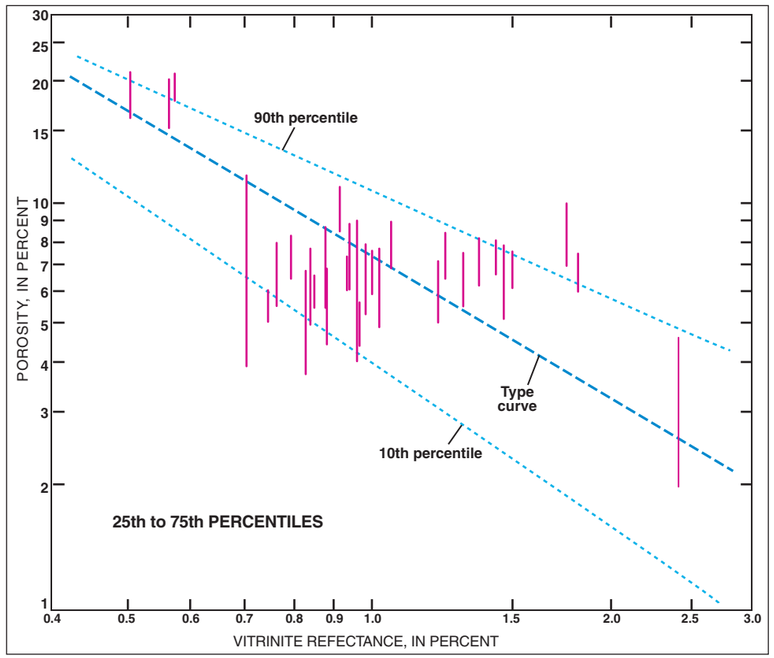
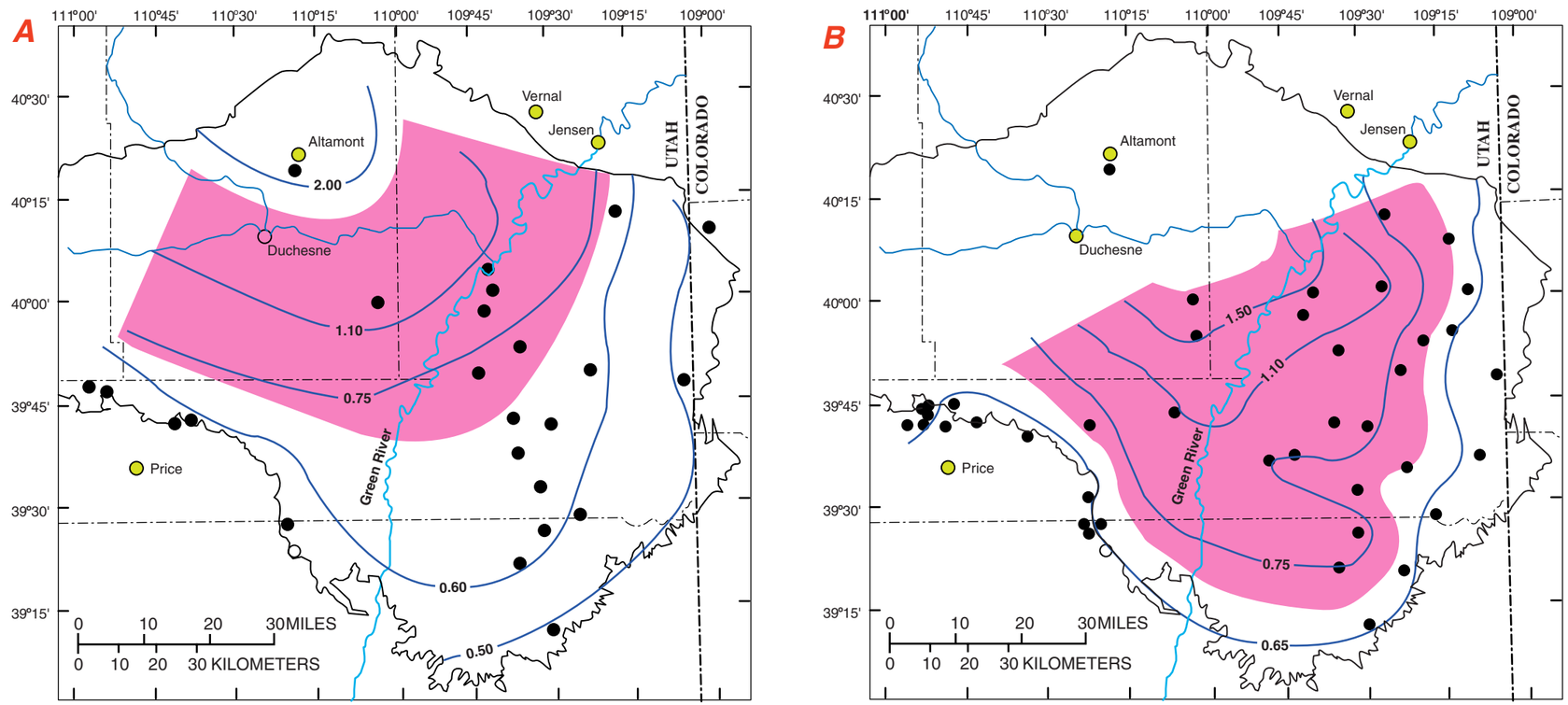


Figure UO-11. Plot of core-plug porosity vs. reflectance for 25th and 75th porosity percentiles (joined by vertical lines) of nonmarine sandstone intervals of the Mesaverde Group, Uinta and Piceance Creek Basins. Mesaverde data are compared with type curve and to 10th and 90th porosity percentiles representing sandstones in general. Note that the porosity does not decrease within the window of hydrocarbon generation (R_O of 0.070-1.8%) (modified after Nuccio et al., 1992).



Figures UO-12A and 12B. Map showing the region (pink area) between R_O 0.70 and 1.8%, where porosity of sandstones at the base of the Mesaverde Group does not decrease as a function of increasing R_O. This region defines the area of optimum gas recovery for **A**, Upper Mesaverde; **B**, Lower Mesaverde (modified after Nuccio et al., 1992).

Mancos Shale

As of December 1990, almost 359.5 BCF of natural gas have been produced from Upper Cretaceous Mancos Shale reservoirs (FIGURE UO-13). Most of the production comes from the silty, tight gas sandstone reservoirs of the Mancos B (also called the Emery Sandstone) in the middle of the Mancos Shale. Gas is also produced from the Mancos A/Morapos Sandstone, a conventional, clean sandstone found in the upper transition zone between the Mancos Shale and the overlying Mesaverde Group (FIGURE UO-14).

The Douglas Creek North Field has produced >5 BCFG from the Upper Mancos/Morapos Sandstone (figure 13). In this area, the Upper Mancos consists of up to 34 feet of mud to coarse-grained, well-sorted sandstone with 20% porosity and 100 mD permeability. It was deposited as shelf sands in a marginal-marine setting, and is probably time-equivalent to the Castlegate Sandstone.

The Mancos B consists of 500 to >1000 feet of finely interbedded and discontinuous claystone, siltstone, and very fine- to fine-grained sandstone, with an average net pay interval of 30-250 feet. It is characterized by low porosities and permeabilities, with porosities ranging from 10-11% on the Douglas Creek Arch, to <2% on the flanks. Permeabilities are <0.1 mD on the average. Mancos B sediments were deposited on a northerly prograding submarine slope or foreslope, approximately 100 miles to the east of the time-equivalent Emery shoreline in Utah (Noe, 1993a).

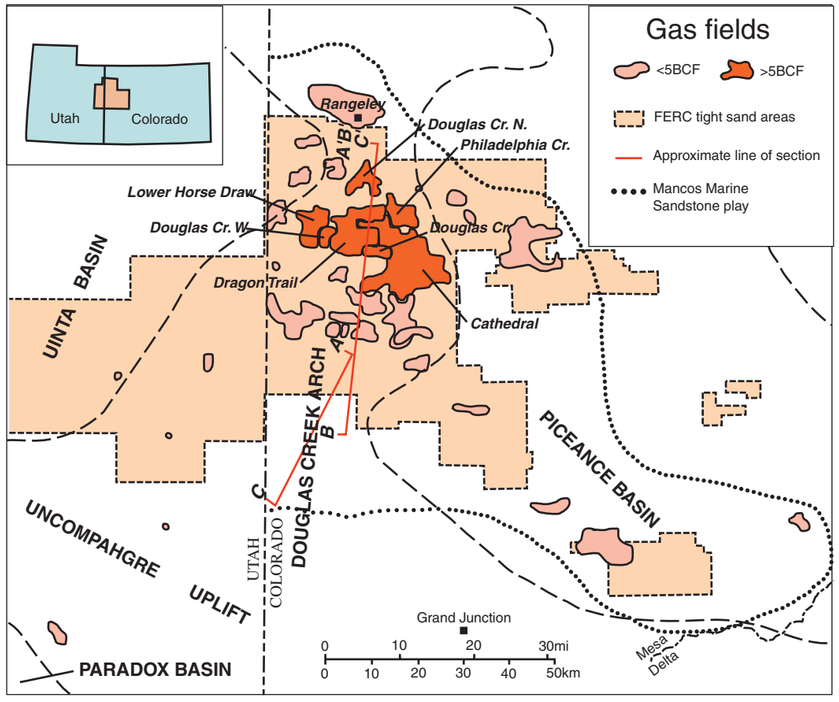


Figure UO-13. Gas fields of the Upper Cretaceous Mancos Shale (modified after Noe, 1993a)

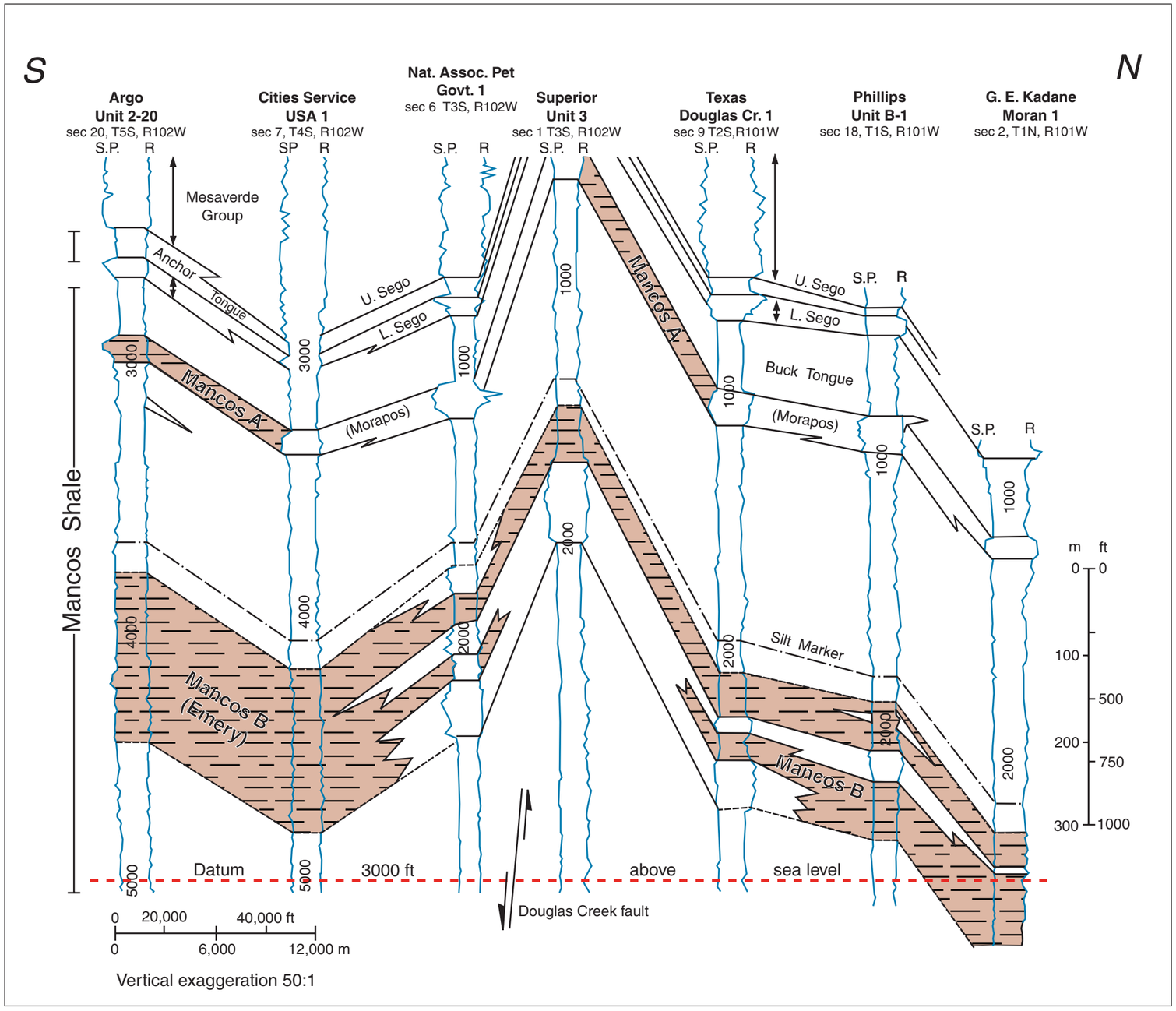


Figure UO-14. South to north structural cross section along the Douglas Creek Arch of the Mancos B interval and other sandstones in the transitional zone between the Mancos Shale and Mesaverde Group (modified after Noe, 1993a).

Dakota Sandstone, Cedar Mountain Formation, Morrison Formation

The Dakota Sandstone, Cedar Mountain Formation, and Morrison Formation are similar in lithologic succession. Each contains a basal, continuous, conglomeratic sandstone or conglomerate, like the Salt Wash Member of the Morrison Formation, the Buckhorn Conglomerate of the Cedar Mountain Formation, and the lower part of the Dakota Sandstone. This is overlain by interbedded shales and lenticular sandstones, like the Brushy Basin Member of the Morrison and the upper units of the Cedar Mountain and Dakota (Figure UO-15). The basal conglomeratic units are braided stream deposits, while the upper units of the Morrison and Cedar Mountain Formations are thought to be floodplain and meandering stream deposits. The Upper Dakota was deposited in a complex coastal setting consisting of coastal plain, fluvial, swamp, marsh, tidal flat, delta, beach, and nearshore marine environments (Fig. UO-16).

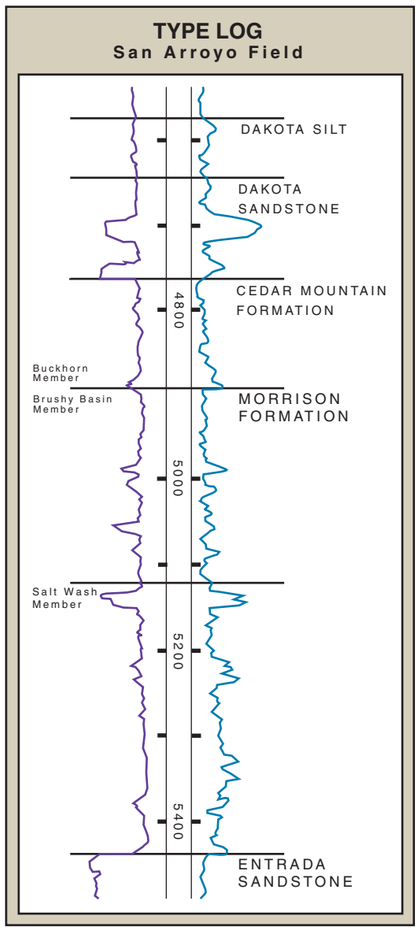


Figure UO-15. Type log from the San Arroyo Field (modified after Hill and Bereskin, 1993).

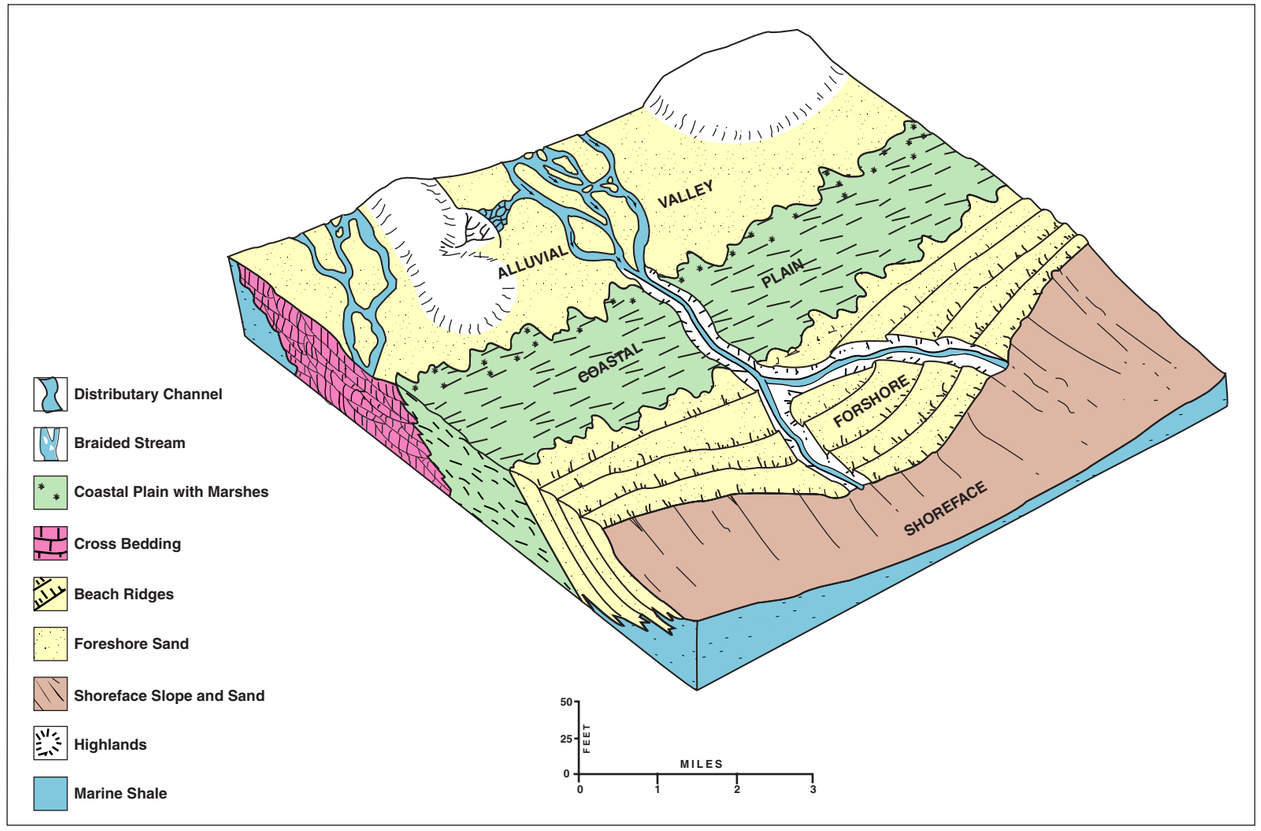


Figure UO-16. Three dimensional model of Dakota Sandstone depositional environments at Hell's Hole Field (modified after Moretti et al., 1992).

The Morrison Formation is approximately 350-450 feet thick, the Cedar Mountain Formation is approximately 0-150 feet thick, and the Dakota Sandstone is approximately 40-250 feet thick (Noe, 1993b).

Entrada Sandstone

In northeastern Utah, the Entrada Sandstone consists of dune and interdune eolian deposits associated with the northerly retreat of a Jurassic sea. The sandstones are gray to orange, fine- to medium-grained, well-sorted and cross-bedded.

Gas and some oil are produced from traps formed by anticlinal closures on Laramide structures. Three Entrada reservoirs have produced >44 BCF gas; most of this production comes from San Arroyo Field (FIGURE UO-17). Average depth to the top of the reservoir varies from 5250 feet at San Arroyo to 6700 feet at Wilson Creek Field in Colorado. Average net pay thickness in the Uinta Basin is 118 feet at Westwater Field. Average porosity ranges from 16% at San Arroyo to 24% at Westwater.

Source rocks for San Arroyo and Westwater Fields may have been organic-rich marine deposits of the Permian Phosphoria and Pennsylvanian Paradox Formations (Morgan, 1993b).

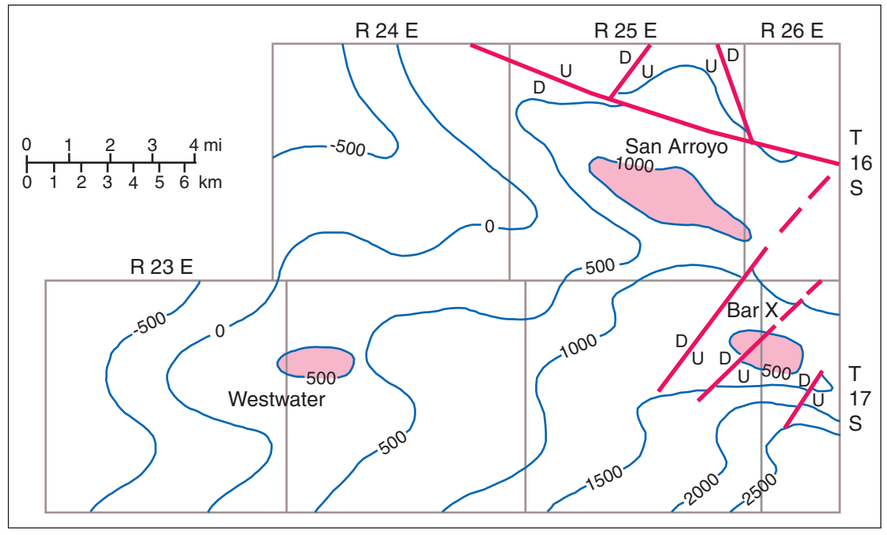


Figure UO-17. Structure contour map of the top of the Entrada Sandstone, San Arroyo/Westwater area, Grand County, Utah. The area that is productive from the Entrada Sandstone is colored in pink. The Bar X Field has produced less than 5 BCF of gas from the Entrada Sandstone. Contour interval is 500 feet (modified after Morgan, 1993b).

Weber Sandstone

The Weber Sandstone is a fine-grained, subarkosic to quartz arenite of eolian origin deposited during Desmoinesian, Missourian, and Wolfcampian time. In Rangely Field, productive eolian sands were deposited in dune, interdune, and extradune environments (FIGURE UO-19). These sandstones are either cross-laminated or massively-bedded, the cross-laminated lithofacies being the major producer with an average porosity of 12%. Permeability along laminae averages 2 mD, while permeability across laminae averages 0.4 mD.

Cumulative production from the Weber Sandstone as of 1990 is 724.7 BCF of associated gas and 772 MMBO. The Rangely Weber reservoir contributed 98.9% of the total gas production (FIGURE UO-18). Average depth to the top of the Weber is 6500 feet, and the trapping mechanism in all Weber reservoirs is anticlinal closure (Hemborg, 1993).

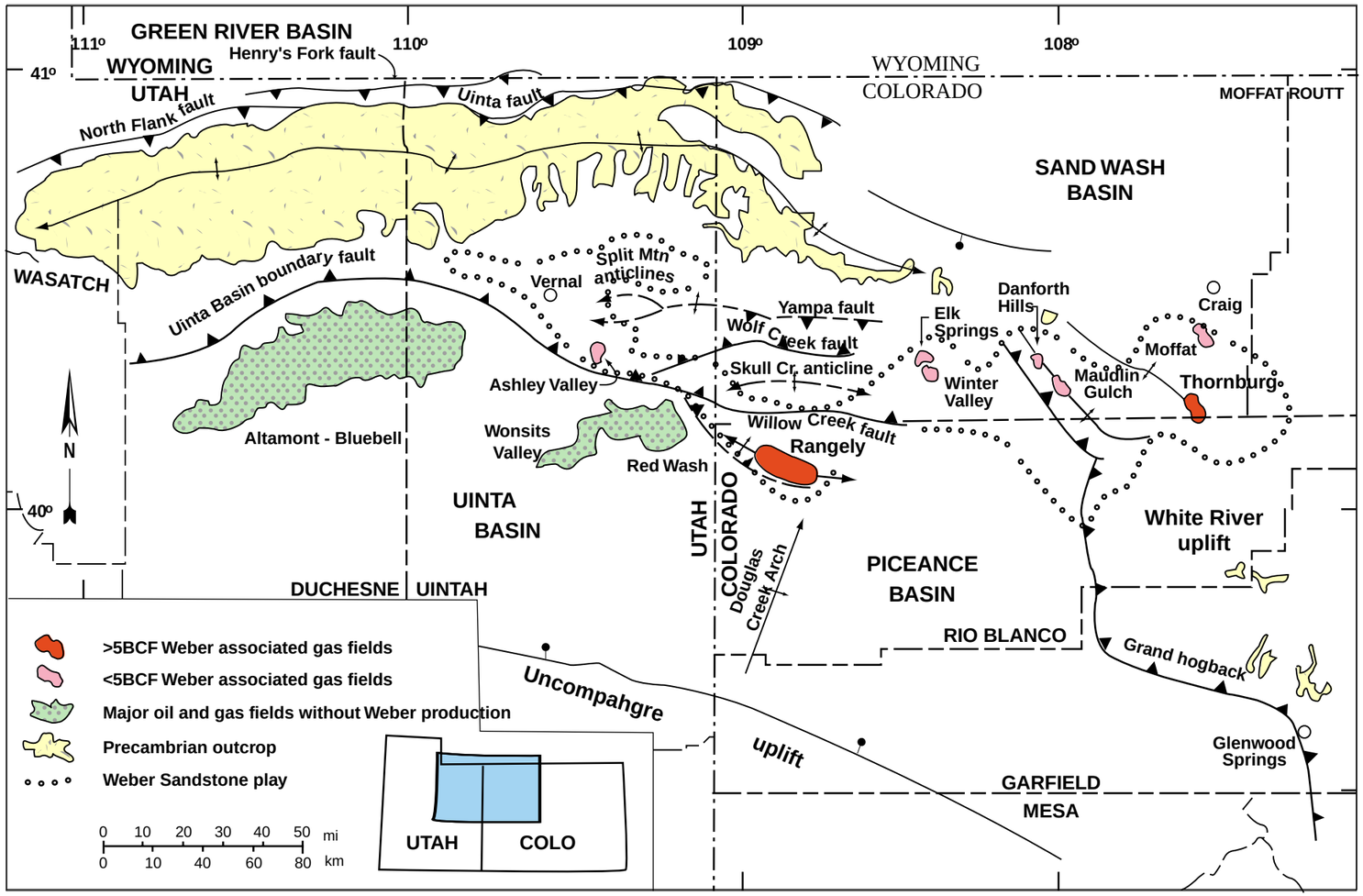


Figure UO-18. Location map of Rangely Field and other major and minor Weber Sandstone reservoirs (modified after Hemborg, 1993).

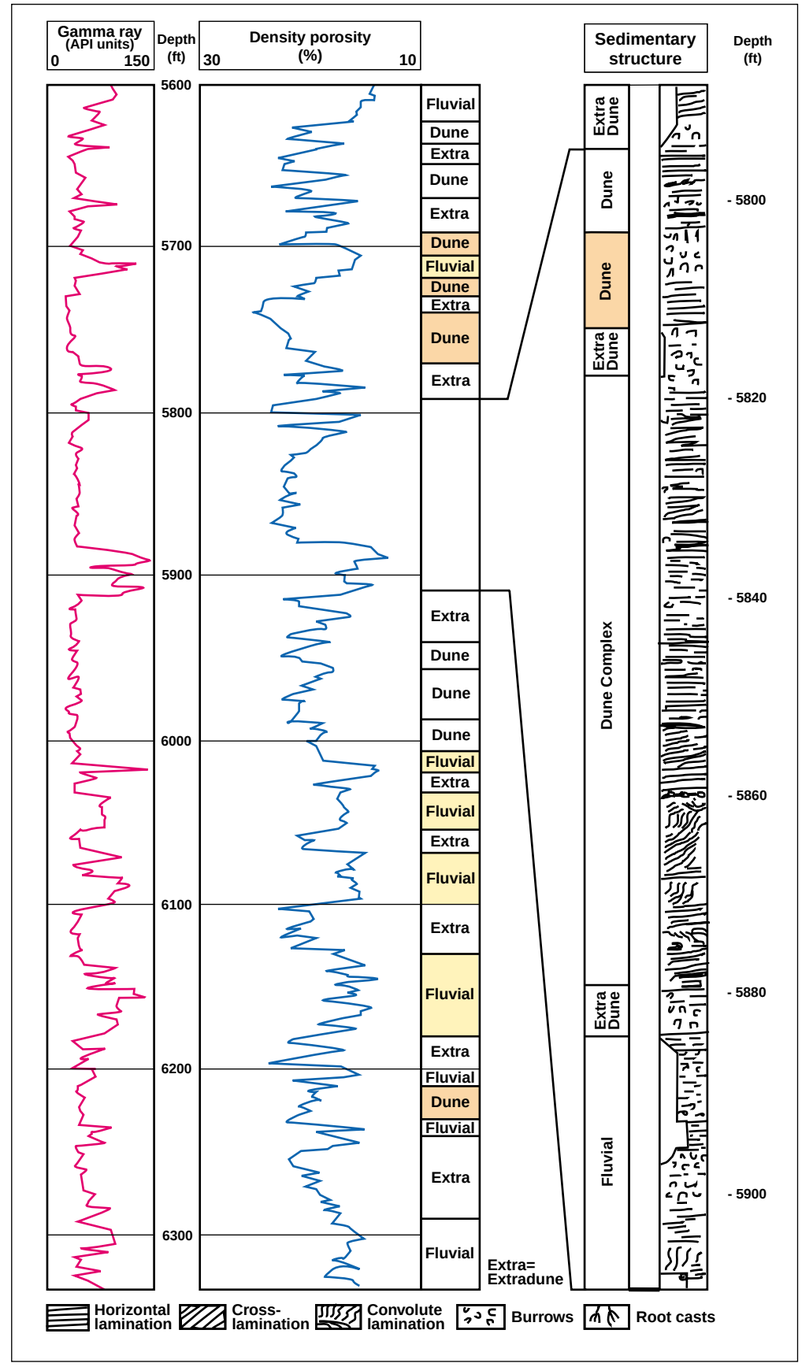


Figure UO-19. Wireline log and core description of the No. 139Y UPRR, Rangely Field. Core shows one cycle of Weber deposition (modified after Hemborg, 1993)

Play Summary

The United States Geological Survey identifies several petroleum plays in the Uinta-Piceance Basin Province and classifies them as Conventional and Unconventional (Gautier et al., 1995). The discussions that follow are limited to those with direct significance for future petroleum development in the Uintah and Ouray Indian Reservation (TABLE 1).

Play Types

Conventional Plays- Discrete deposits, usually bounded by a downdip water contact, from which oil, gas or NGL can be extracted using traditional development practices, including production at the surface from a well as a consequence of natural pressure within the subsurface reservoir, artificial lifting of oil from the reservoir to the surface where applicable, and the maintenance of reservoir pressure by means of water or gas injection.

Unconventional Plays- A broad class of hydrocarbon deposits of a type (such as gas in tight sandstones, gas shales, and coal-bed gas) that historically has not been produced using traditional development practices. Such accumulations include most continuous-type deposits.

Reservation: Uintah and Ouray
Geologic Province: Uinta-Piceance Basin
Province Area: 40,000 sq. miles (25.6 million acres)
Reservation Area: 6250 sq. miles (4 million acres)

Total Production in Province as of 1996 — Uinta-Piceance Basin
Oil: 486,712 MBO
Gas: 1,992,627 MMCFG
NGL: 40,262 MBNGL

Undiscovered resources and numbers of fields are for Province-wide plays. No attempt has been made to estimate number of undiscovered fields within the Uintah and Ouray Indian Reservation.

Play Type	USGS Designation	Description of Play	Oil or Gas	Known Accumulations	Undiscovered Accumulations > 1 MMBOE Field Size and Number	Play Probability (chance of success)	Drilling depths (min., mean, max.)	Pay Thickness	Porosity/Permeability
Uinta Tertiary Oil and Gas Play 1	2002	Fluvial and lacustrine sandstones in the Wasatch and Green River Formations.	Both	Gas (917,288 MMCFG) Oil (485,592 MBO)	**Field Size (median, mean)** Gas (15 BCFG, 18.9 BCFG) Oil (2 MMBO, 2.8 MMBO) **No. of Undiscovered Fields (min., median, max., mean)** Gas (2, 6, 15, 7.1) Oil (4, 13, 30, 14.7)	1	Gas (500, 3000, 6000)ft Oil (1000, 5000, 14000)ft	Variable	10-15%/v, low to 1000 md
Upper Cretaceous Conventional Play 2	2003	Shallow sandstones of the Mesaverde Group.	Mostly Gas	Gas (129,540 MMCFG)	**Field Size (median, mean)** Gas (12 BCFG, 15.2 BCFG) **No. of Undiscovered Fields (min., median, max., mean)** Gas (10, 23, 50, 25.9)	1	Gas (500, 3500, 6000)ft	up to 80 feet	8-18%/<0.1md
Cretaceous Dakota to Jurassic Play 3	2004	Fluvial Dakota Sandstone, discontinuous fluvial Morrison Sandstone, blanket eolian Entrada Sandstone.	90% Gas 10% Oil	Gas (579,169 MMCFG)	**Field Size (median, mean)** Gas (10 BCFG, 13.1 BCFG) Oil (1 MMBOE, 1.5 MMBOE) **No. of Undiscovered Fields (min., median, max., mean)** Gas (3, 15, 25, 14.6) Oil (1, 2, 4, 2.2)	1	Gas (500, 3500, 6000)ft Oil (1000, 4000, 6500)ft	Dakota - 25 feet Buckhorn - 26 feet Morrison - 11 feet	10-25%/ Unknown Permeability
Permian-Pennsylvanian Sandstones and Carbonates Play 4	2005	Very high risk Permian-Pennsylvanian sandstones and carbonates.	Mostly Oil	Oil EUR (980.5 MMBO) Gas EUR (>706 BCFG)	**Field Size (median, mean)** Oil (9 MMBO, 25.0 MMBO) **No. of Undiscovered Fields (min., median, max., mean)** Oil (1, 4, 15, 5.7)	1	Oil (6000, 10000, 12000)ft	275 feet	11-14%/ Unknown Permeability
Basin Margin Subthrusts Play (hypothetical) 5	2014	Closures beneath thrusts, reservoirs range from Paleozoic to Tertiary in age.	Both	**N/A**	**Field Size (median, mean)** Oil (2 MMBO, 5.3 MMBO) Gas (15 BCFG, 25.0 BCFG) **No. of Undiscovered Fields (min., median, max., mean)** Oil (1, 2, 7, .05) Gas (1, 3, 10, .07)	0.18	Oil (5000, 12000, 18000)ft Gas (5000, 14000, 25000)ft		Unknown
Cretaceous Self-Sourced Fractured Shales Play (hypothetical, continuous) 6	2009	Upper Mancos fractured shale. Best fracturing occurs in brittle siltstones, carbonates, and calcareous shales.	Both	Oil EUR(14 MMBO)	Per well EUR estimates vary	1	Oil/Gas (500, 2800, 6000)ft	10->50 feet	10-20%/0.01-100md
Tight Gas Uinta Tertiary East Play (continuous) 7	2015	Medium- to fine-grained fluvial sandstones interbedded with mudstones, siltstones, shales, and some coal of the Wasatch Fm.	Gas	**N/A**	**N/A**	1	Gas (3000, 6400, 10500)ft	up to 80 feet	<5-9%/<0.1md
Tight Gas Uinta Tertiary West Play (hypothetical, continuous) 8	2016	Medium- to fine-grained fluvial sandstones interbedded with mudstones, siltstones, shales, and some coal of the Wasatch Fm.	Gas	**N/A**	**N/A**	1	Gas (4500, 7500, 11000)ft	up to 80 feet	4-8%/<0.01md
Basin Flank Uinta Mesaverde Play (hypothetical, continuous) 9	2018	Based on widespread occurrence of tight, gas-saturated continental and marginal marine sandstone.	Gas	**N/A**	**N/A**	1	Gas (8000, 9500, 15000)ft		4->12%/<0.1md
Deep Synclinal Uinta Mesaverde Play (hypothetical, continuous) 10	2020	Based on expected occurrence of gas-saturated tight Mesaverde Sandstone at depths >15,000 feet.	Gas	**N/A**	**N/A**	1	Gas (15000, 20000, 25000)ft	N/A	3-8% Unknown permeability

Table 1. Play summary chart.

Conventional play type **Unconventional/Hypothetical play type**